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Transfer of earthworms (Lumbricidae, Oligochaeta) for soil amelioration in the USSR

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1. Introduction

The tremendous importance of earthworms in soil formation and in maintenance of soil fertility makes these animals desirable inhabitants of various agricultural and afforested lands. But earthworms, especially the most efficient beneficial species of them, are often absent from the soil of a given territory. Such a situation exists when the territory has been isolated from the range of natural distribution of an earthworm species for a geologically long time. The active migration ability of earthworms is rather insignificant; and the majority of species can crawl only a few metres, seldom spreading more than 10—20 metres per year. The principal mode of earthworm dispersal is passive, e.g. by washing off and transportation after heavy rains, when earthworms come to the soil surface and can be carried in surface waves.

Egg capsules of earthworms sticking to the legs of birds, ungulates and other animals, can be carried by them.

2. Occasional distribution of earthworms by man

Anthropochorous transportation is of a paramount significance for earthworm dispersal. Until recently it occurred only accidentally. In the time of sailing fleets the Lumbricidae were carried occasionally with earth ballast by ships sailing without goods from Europe to various overseas destinations localities of other continents (Lindroth 1957). Earthworms have often been transported with living plants destined for planting in new localities.

Palearctic Lumbricidae species which have had invaded territories after glaciation and are now widely distributed have been called by Michaelsen (1903) peregrine. Many of these peregrine species are eurybiotic, following man easily, some surviving soil cultivation and able to inhabit soils of various type. Such species became almost cosmopolitan; e.g. *Nicodrilus caliginosus* (Sav.) originally European has become now common to North and South America, southern and eastern Asia, Africa, Australia, New Zealand etc.

In the new parts of its range this species (as well as some other peregrine Lumbricidae species of European origin) becomes distributed not only over arable lands but actively penetrates into uncultivated areas too, e.g. in Canada in podzol soils under natural forests consisting of indigenous trees (*Abies balsamea*, *Picea rubra*, *Populus tremuloides*, *Sorbus americana* etc.) in territories having undergone glaciation there were no earthworms and in many such areas these animals are still wanting nowadays.

LANGMAID (1964) in such forests in New Brunswick, where there were no Lumbricidae in 1958, found later in 1961—1962 five sites invaded by earthworms. Their invasion resulted in a rapid decomposition of the litter, a change of the coloration of the podzolic horizon rich in iron. The thin accumulative horizon, litter and upper 5 cm of the podzolic horizon became in a short time a homogeneous dark grey layer. This shows that the earthworm activity even in unfavourable acid soils ($pH = 4.8$) has changed the soil. In sites studied by LANGMAID only European earthworm species occurred — *N. caliginosus*, *Lumbricus festivus* (SAV.) and *L. terrestris* L.

Lumbricidae occasionally imported by man into New Zealand penetrated the cover of autochtonous vegetation suppressing representatives of indigenous families of Megadrili (LEE 1957). Analogous examples from Mt Kosciusko in Australia were discussed by WOOD (1974).

In some cases an acclimatization of imported species takes place which are much more stenobiotic than peregrine ones. This is illustrated by observations made in the USSR. In chernozem soils under virgin Stipeto-Festuceta steppes in the Kherson region (southern part of the Ukraine) the only lumbricid species — *Nicodrilus roseus* (SAV.) occurs. Our counts in various sites of reversed virgin steppe showed that its population density does not exceed a ten individuals per 1 m^2.

In the last century a famous reserve territory — Natonal Park Ascania Nova was organized, where a dendrological park was planted containing many species of West-European trees, by infiltration watering with artesic water. Our study of the soil fauna in this revealed a high population density of the West-European earthworm *Allolobophora chlorotica* SAV. (green variety). This worm is distributed widely here under the tree cover especially along the banks of irrigation canals (60—100 ind. 1 m^2). This species does not occur in Ascania Nova outside the irrigated part of the dendrological park territory. There is no doubt that this species was carried occasionally to Ascania Nova with tree seedlings and found a favourable environment in the irrigated soil under the tree canopy. The range of natural distribution of *A. chlorotica* in the USSR is limited to the western regions — Baltic Republics and Bielorussia (PEREL' 1979).

In the Moscow Region (village Kostino, Pushkin rayon) there was found a numerous population of an even more stenobiotic West-European species — *Nicodrilus ictericus* (SAV.), which invaded a territory around a pond (MATVEEVA & PEREL' 1982). This species has adapted itself quite well to this habitat, but is dispersing only very slowly. *N. ictericus* was probably carried in with plants at the beginning of this century, when a glass-house existed on the bank of the pond. In other localities of this country this species does not occur under natural conditions. These examples proved that not only peregrine species but also more stenobiotic ones can acclimatize outside their initial range in ecologically favourable biotopes.

3. Introduction of earthworms into desert soils after irrigation in Uzbekistan and Turkmenia

In many sites where earthworms are absent but where conditions are favourable for their existence it is possible to colonize lumbricid species artificially.

In the 1930's DIMO (1938) and BRODSKIJ (1937) wrote that in virgin sierozems (desert grey soils) and under crops grown on these soils without irrigation in Uzbekistan there were no earthworms.[1] But on old irrigated land the population density of earthworms was high, up to 100—150 individuals m^{-2} (DIMO 1938). Endemic species (about 15) characteristic of the Middle Asian mountain ranges (PEREL' 1969), from where rivers supplying irrigation systems run, do not inhabit irrigated fields. Eurybiotic peregrine species as *Nico-*

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[1] Similar data were later obtained for sierozems in Tadjikistan (VALIACHMEDOV & PEREL' 1961).

drilus caliginosus (Sav.) *f. trapezoides* A. Dug., *N. roseus* (Sav.) *f. parashadi* Steph. are distributed in irrigated sierozem fields. These West Palearctic worms are associated with old farms in Middle Asia.

The occasional transport of earthworms to new isolated irrigated fields which are situated a long distance from old arable land and separated by desert is very slow.

Experimental earthworm transfer and their inoculation were initiated. The first planned earthworm introduction in this country was into the isolated new cases with artesian watering in Kyzyl-Kum desert (Bokhara Region) in 1963 (Ghilarov & Mamajev 1966). Mixed populations of earthworms sampled on the shrub covered slopes of the Zeravshan river were brought in big jute sacks with the soil from the sampling area to the destination sites (ca. 177 km) by a motor lorry and settled in 1 m^3 pits filled with carried and local soil and plant debris (200—1,000 individuals per 1 pit). Earthworm species transported into cases which survived were *N. caliginosus trapezoides* and *N. roseus (f. prashadi)*. Soil samples after 2 years showed that earthworms had dispersed about 10 m from sites of inoculation and their population density in invaded areas reached 150 individuals of various ages per 1 m^2. According to scientists of the Institute of Zoology (Academy of Sciences of Uzbekistan) in Tashkent sampling earthworms in lucerne fields of the Kyzyl-Kum Botanical Station and in Mubarek in 1975—1981 showed that earthworms had spread over almost the whole irrigated territory, actively transforming plant debris on fields and sheep dung on pasture.

A similar experiment using the same method of transfer was done in Turkmenia along the newly constructed Karakum irrigating canal track. Jagdyev (= Yagdyev 1969) transported in 1965 earthworms of the species *N. caliginosus trapezoides* to a newly irrigated lucerne field of the state farm Tedjen. Earthworms were taken from old cultivated irrigated land near the city of Mary. The method of colonization was the same. Another inoculation of this species was done in a newly irrigated lucerne field and a watered vineyard on clay soil near Khaus-Khan. Inspections in the autumn and in the following year showed that earthworms had spread up to 30 m from the point of inoculation, their intensive propagation took place. In both experiments in irrigated deserts the most suitable species was the peregrine *N. caliginosus trapezoides*, which easily adjusted itself to irrigated arid soils. Just this species was found also in an isolated oasis Tazeruk in the Sahara dry desert (Wilcke 1956).

The success of earthworm acclimatization in these extremely unfavourable arid conditions depends on the watering regime. In sites where the water supply ceases at the end of the summer (in connection with irrigating water economy) the soil becomes too dry for earthworms and their population density drops. The most appropriate species to survive dry conditions is *N. roseus f. prashadi*.

4. Transportation of deep burrowing earthworms into orchards of Trans-Ili Alatau mountains

An experiment of another character was made in vast apple orchards on rather steep slopes of the Trans-Ili Alatau mountain range in the vicinity of Alma-Ata (Kazakhstan). In these orchards on slopes an erosion of the surface soil layer with run off precipitation water takes place. Those earthworms species which are distributed and abundant in these orchards *(N. caliginosus trapezoides, Lumbricus rubellus* Hoffm., *Dendrobaena octaedra* Sav. and *N. roseus)*, whose total population density was often more than 200—300 ind. m^{-2} (Džangaliev & Belousova 1969) do not make such deep permanent vertical burrows as deep burrowing species, e.g. *Lumbricus terrestris* L. The anti-erosion effect of earthworm species occurring in Trans-Ili Alatau mountains is not so great as that of deep burrowing species would be.

In another mountain range of Kazakhstan, in Djungar Alatau under cover of natural apple tree forests Belousova found big earthworms making deep vertical burrows and contributing to a rapid infiltration of precipitation water into the soil. diminishing its surface washing off and erosion. This worm was not known previously and is described by PEREL' (1969) as *Allolobophora djungarica* (now *Eisenia djungarica* [PEREL' 1969]). In spring 1969, BELOUSOVA and authors have transported this species from apple tree forests of Djungar Alatau into apple orchards of Trans-Ili Alatau in the suburb of Alma-Ata situated at an altitude of 1,300—1,350 m (corresponding to that of the forest from where *E. djungarica* was imported). The method of inoculation of worms was changed in this experiment. Five specimens of these rather large worms were put into small pit (20 × 20 cm) filled with orchard soil mixed with that carried from the forest. Pits were clustered in different parts of the orchard, 5 pits in very cluster a few metres one from another.

In 1973, BELOUSOVA checked the results of *E. djungarica* acclimatization. These earthworms survived, they started to reproduce (many egg cocoons and young individuals) but did not spread far from the places of inoculation — 10—15 m down the slope, 5 m in other directions, their population density being no higher than 10 ind. m^{-2}. Representatives of the deep burrowing worms dispersed slower than species belonging to other life-forms discriminated by PEREL' (1975, 1977). *N. caliginosus trapezoides* is the species surviving most easily when inoculated in some plots of these orchards (BELOUSOVA 1975).

5. Acclimatization of earthworms in artificial forest plantations in the semi-desert zone

Soil-litter dwelling earthworms spread much more rapidly than deep burrowing, as has been proved in experiments with *Eisenia nordenskioldi* (EISEN) by PEREL (1975). In the clay desert northward of the Caspian sea (Ural Region) there is no natural arboreal vegetation and no earthworms under herbaceous vegetation. Only in deep depressions there are shrub thickets of *Spirea* sp., *Prunus spinosus*, *Lonicera tatarica* etc.

In these difficult afforestation conditions forest shelter belts and small forest plantations were planted in 1951, the last ones in shallow closed depressions (more than one ha each) on an azonal dark-coloured soil at the Djanybek Afforestation Experimental Station.

The breakdown of the leaf-litter (oak, maple, elm) in these plantations is mainly performed by Diptera larvae (*Tipula peliostigma* SCHUM., *Bibio marci* L.). Faeces of these insects consist principally of black organic matter and accumulate at the soil surface, forming humus of the morphological type called "moder".

Earthworms such as *E. nordenskioldi*, mix the transformed undigested plant debris with mineral particles, promote mull formation, create waterproof grainy aggregates and involve plant remnants into mineral soil layers improving soil properties. An attempt was made to populate afforested plots with *E. nordenskioldi*. This species is known from ravine oak forests of the steppe zone of the Ukraine and is also penetrating into forest shelter belts in the rather dry steppe (GILJAROV 1956).

Populations of *E. nordenskioldi* were sampled in spring 1966 in a flooded forest on the bank of the Eruslan river (tributory of Volga) and inoculated into two planted stands in Djanybek — one consisting of oak *(Quercus pedunculata)* another of elm *(Ulmus microphyllus)*. In every stand, ca. 400 individuals were inoculated in a pit (100 × 100 cm) filled with the soil brought from the forest where animals had been sampled. Check sampling in April 1969 showed that in the oak stand all stages of development of *E. nordenskioldi* occurred at distances up to 10 m from the site of their inoculation. Single individuals of *D. octaedra*, *N. roseus* and *Eisenia uralensis* MAL. were also transported with the soil taken from the forest. In an elm stand situated near the drier border of the depression only adult earthworms *(E. nordenskioldi)* were found near the point of their inoculation. In spring 1974, quantitative samples (8 cores, 50 × 50 cm) showed that *E. nordenskioldi* had spread over the whole territory of the oak stand (0.5 ha) and the population density was 16 ind. m^{-2}. Similar sampling in spring 1974 showed that *E. nordenskioldi* had penetrated into another neighbouring oak stand (ca. 0.5 ha) and its population density had reached 91. Its population density in April 1983 was at the same level (89 ind. m^{-2}). In various neighbouring planted tree stands (oak, maple, elm) *E. nordenskioldi* was also found in 1983.

This proves that *E. nordenskioldi* is very suitable to settle afforested areas, even in very dry regions, where the annual precipitation is less than 300 mm (in Djanybek mean value 274 mm per 1 year). This species spreads very quickly in forest plantations invading all suitable habitats and reaching high population densities.

In the vicinity of Djanybek *N. roseus* occurs also in some orchards. This species was sometimes found in dark coloured soil in depressions under tree stands, but it is distributed very locally on small areas, where its population density reaches 120 individuals per soil core (0.25 m^2), but does not disperse quickly.

These data show that different species require different methods of release at acclimatization in new territories. Deep burrowers such as *E. djungarica* and small mineral soil layer dwellers, such as *N. roseus*, must be inoculated in a maximally diffuse way. Soil-litter dwelling species *(E. nordenskioldi)* and larger soil layer inhabitants *(N. caliginosus trapezoides)* can be released in fewer sites taking into account their ability to disperse actively from the sites of release.

6. Transfer of Lumbricidae in other countries

These remarks on introduction of Lumbricidae abroad do not serve as an exhaustive review. Fruitful experiments with artificial inoculation of earthworms into newly dried sea-bottom polders in The Netherlands have been done by VAN RHEE (1969a, b). In this case *N. caliginosus* was used.

Experiments in pasture amelioration by application of this species in New Zealand (WATERS 1951; STOCKDILL 1982) and in Australia (BARLEY 1961; BARLEY & KLEINIG 1964) are well known. *N. caliginosus* seems to be effective when recultivating coal shiste deposits (DUNGER 1969). In all these successful experiments peregrine species, namely *N. caliginosus*, were used.

The practice in this country shows that more stenobiotic species can also be used for soil amelioration.

Introduction of earthworms into new territories, as well as experiments with acclimatization of dung beetle *Ontophagus gasella* F. into pastures of Australia (BORNEMISZA 1970, etc.) are examples of that trend of the soil zoology development which can be named "zoological soil amelioration" (GILJAROV 1976, 1979). Methods of earthworm introduction in new habitats require a further elaboration.

7. Резюме

Случайный завоз и акклиматизацир в новых условиях люмбрицид, особенно перегринных видов, становящихся важным фактором плодородия почвы, общеизвестны. В местностях, где по историческим причинам эффективных видов дождевых червей нет, но где они могут по экологическим условиям существовать, рекомендуется осуществлять их завоз.

В СССР такой завоз успешно осуществлен в ряде местностей.

1. В оазисы артезианского орошения в Узбекистане — *Nicodrilus caliginosus trapezoides* (DUG.), *N. roseus f. prashadi* STEPH.
2. В районах нового орошения Каракумским каналом в Туркмении (те же виды).
3. В садах Заилийского Алатау — *Eisenia djungarica* (PEREL).
4. В лесопасадках глинистой полупустыни Уральской области — *Eisenia nordenskioldi* (EISEN).

Почвенно-подстилочные виды и такие активно расселяющиеся, как *N. caliginosus trapezoides*, можно вносить на участок в меньшее число точек, чем норников и таких собственно-почвенных видов, кяк *N. roseus*, которые требуют более диффуного внесения.

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Synopsis: *Subject review article*

GHILAROV, M. S., & T. S. PEREL', 1984. Transfer of earthworms (Lumbricidae, Oligochaeta) for soil amelioration in the USSR. Pedobiologia **27**, 107—113.

Transportation and acclimatization of Lumbricidae especially peregrine species into new conditions as a significant factor of soil fertility improvement is well known.

In localities where suitable Lumbricidae species are wanting, but where these species can exist their transfer is recommended.

Such transfers were successful in USSR in various localities:

1. In artesic irrigated new oases in Kyzyl-Kum desert *Nicodrilus caliginosus trapezoides* (SAV.), *N. roseus* (SAV.) *f. prashadi* STEPH.
2. In new territories irrigated by Karakum canal in Turkmenia the same species.
3. In orchards of Trans-Ili Alatau *Eisenia djungarica* (PEREL).
4. In forest plantation of Trans-Volga semi-desert *Eisenia nordenskioldi* (EIS.).

Soil-litter species and such actively spreading species as *N. caliginosus trapezoides* can be released in fewer sites in new territories than deep burrowing species. Mineral soil layer dwellers as *N. roseus*, need to be inoculated in a more diffuse manner.

Key words: earthworm, soil amelioration, introduction, erosion, improvement, Nicodrilus caliginosus, Eisenia djungarica, Eisenia nordenskioldi.